Estimation of Forest Canopy Attenuation by a Time-Domain Analysis of Radar Backscatter Response

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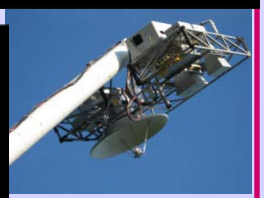
1 BACKGROUND

- **Soil moisture** is recognized as an important component of the water, energy, and carbon cycles at the interface between the Earth's surface and atmosphere.
- Advances in L band microwave science and technology have led to the upcoming **SMOS** (2009) and the recently approved **SMAP** (2013) missions.
- The current baseline soil moisture retrieval algorithms for these missions have been developed and validated only over grasslands, agricultural crops, and generally light to moderate vegetation.
- **Tree areas** have generally been excluded from operational microwave soil moisture retrieval plans due to the large expected impact of trees on masking the microwave response to the underlying soil moisture.
- To improve our understanding of **the microwave properties of trees** such as **attenuation** and **scattering** and their effects on **soil moisture** retrieval algorithms for the future space-borne soil moisture missions.

3 COMBINED RADAR/RADIOMETER (ComRAD)

- The ComRAD microwave instrument system consists of
  - dual-polarized 1.4 GHz **total-power radiometers,** (LH, LV)
  - a quad-polarized 1.25 GHz **L-band VNA based radar,**
  - ***sharing a single parabolic dish antenna*** with a novel broadband stacked patch dual-polarized feed.

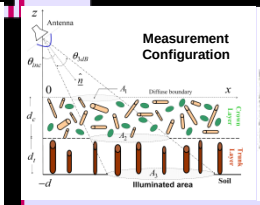


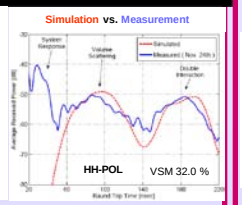
4 FIELD EXPERIMENT

- During radar measurements, the truck boom is rotated in a conical scan arrangement with a 60° **sweep in azimuth.**
- **Location** : Upper Marlboro, Maryland USA
- **The ground:** flat and the cover under the tree canopy consists of relatively short grass.
- **Soil texture** : a loamy sand, consisting of 80.3% sand and 6.8% clay.
- **Volumetric Soil Moisture** : (VSM) ranges from %20 to %35
- **Tree height** : Variable on the order of 11-14 m
- **Diameters at breast height** : (dbh) range from 17 to 23 cm
- **Basal Area** : 122 m^2 / hectare

- Radar data has been acquired at the height of **19 m over ground** with incidence angles of 15°, 25°, 35°, and 45°.

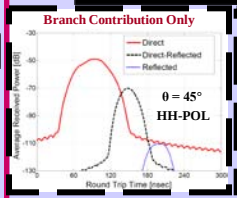
5 TRANSIENT RESPONSE MODEL

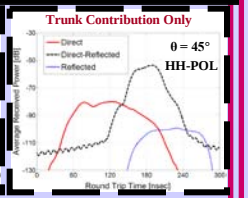




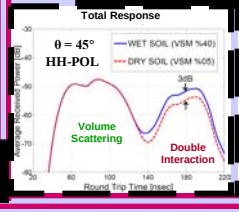
- **A coherent scattering model**, based on a **Monte Carlo simulation,** is developed.
- **Distorted Born Approximation (**the single scattering approximation) is assumed.
- Individual backscatterings from each discrete scatterer are **summed coherently**.
- Frequency domain solutions ***E(f)*** **at discrete frequency points (201 points)** are calculated.
- An inverse discrete Fourier transform (**IDFT**) on this backscattered field is performed.
- An average time domain response ***e(t)*** is obtained by a **sufficient number of realizations of trees** through Monte Carlo.
- This follows closely the data acquisition and signal processing technique employed by network analyzer-based radars (**stepped frequency measurements**).

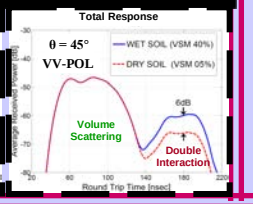
6 INDIVIDUAL SCATTERING CONTRIBUTIONS





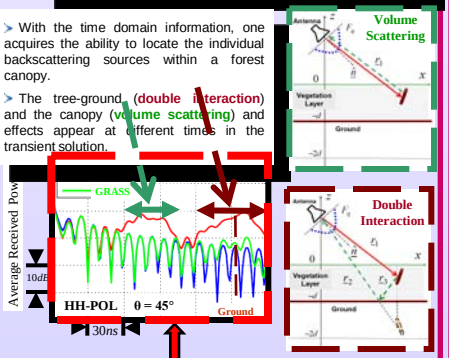
7 EFFECT OF SOIL MOISTURE





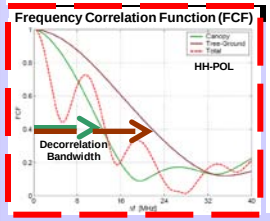
8 A NEW TECHNIQUE TO ESTIMATE FOREST CANOPY ATTENUATION

- With the time domain information, one acquires the ability to locate the individual backscattering sources within a forest canopy.
- The tree-ground (**double interaction**) and the canopy (**volume scattering**) and effects appear at different times in the transient solution.



Measured Transient Response from Trees to L-Band Stepped-Frequency Radar

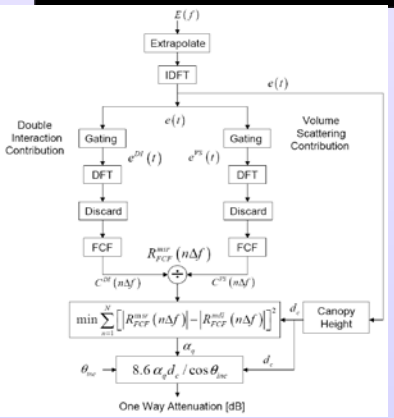
- The time difference between these two scattering mechanisms results from the fact that they have **different path lengths**.
- One can separate the **radar signatures** by performing **a time gating operation** on the measured time-domain response.
- The frequency-domain responses of the separated signatures are obtained by transforming them back to the frequency-domain.
- Using these transformed returns, the **frequency correlation functions (FCF)** of each contribution are generated **for difference frequencies** in the bandpass of the radar system.



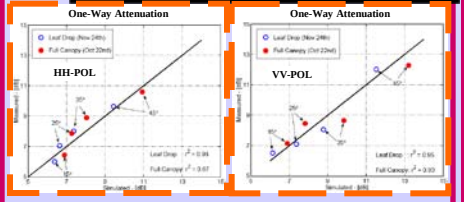
- The FCF of the **total response** oscillates and its decorrelation bandwidth is **very small**.
- On the other hand, the separated returns have a distinct correlation behaviors
- Decorrelation bandwidth of **tree-ground** return is higher than that of **canopy** return.
- This is due to the organized structure of the trunks as compared to the tree canopy

- By normalizing the FCFs of these contributions, one obtains **a ratio** which is **independent** from **system characteristics** such as antenna gain.
- The ratios $\mathbf{R_{FCF}(n\Delta f)}$ are calculated for **an array of difference frequencies** over the system bandpass.
- They provide **a system of equations** depending only on **canopy thickness** d_c, **canopy attenuation** α_q, **a combined parameter** Y_q involving the forest scattering coefficients and the ground reflectance.
- A least square method is used to solve for the α_q and the Y_q assuming the d_c is known *a priori*.
- The d_c is determined from vertical projection of the **time span** of the first backscatter power peak.

9 DATA PROCESSING SCHEME



10 RESULTS



11 CONCLUSION & FUTURE WORK

- A **new** technique for determining the **canopy attenuation** using the measured **stepped frequency** radar backscatter response has been proposed [1].
- The technique has been validated and its sensitivity to **physical conditions** (leaf drop), polarization (HH and VV), and incidence angles (15°, 25°, 35°, and 45°) has been demonstrated.
- We are currently working on the extension of the technique for the SAR data acquired from air-borne and space-borne platforms.

12 REFERENCE

[1] M. Kurum, R. H. Lang, P. E. O'Neill, A. T. Joseph, T. J. Jackson, and M. H. Cosh, "Estimation of Forest Canopy Attenuation at L-band by a Time-Domain Analysis of Radar Backscatter Response", *IEEE Trans. Geosci. Remote Sensing*, Submitted for publication (*Microrad'08* Special Issue)